

A 10-year bibliographic analysis of extracorporeal membrane oxygenation (ECMO) literature

A 10- year bibliographic analysis of ECMO literature

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Abstract

Aim: Extracorporeal membrane oxygenation (ECMO) is a life support device providing extracorporeal artificial support to the respiratory system and/or circulatory system for patients who do not benefit from conventional therapies.

Material and Methods: A bibliometric search was conducted with information obtained from the Web of Science (WoS) database. Publications on ECMO since 2014 were analyzed. Type of the articles, top authors, language, funding agencies, affiliations, countries, journals were determined. Following statistical analysis of the literature, the top 10 articles on ECMO were investigated in detail.

Results: A total of 7940 articles were involved in the study. The majority of the articles were original articles (n=6130, 77.2%). The most productive author was Brodie D (1.9%). English was the most common language. When countries were compared in terms of the number of publications and total citations, the US was the leading country in both categories (n=3103, n=42744, respectively). ASAIO Journal had the highest number of articles (n=491). The analysis of the top 10 most cited articles revealed that the majority of the articles were related to COVID-19.

Discussion: Bibliometric studies on a specific subject may shed light on the management of diseases. When the top 10 articles are considered, the use of ECMO in patients with COVID-19 dominates the scientific literature on ECMO.

Keywords

Extracorporeal Membrane Oxygenation, Bibliometrics, Publications

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Introduction

Extracorporeal membrane oxygenation (ECMO) is a rescue therapy widely used in patients with cardiopulmonary emergencies [1]. Clinical use of ECMO involves severe pulmonary failure, cardiogenic shock, circulatory instability during high-risk percutaneous coronary interventions (PCI) and persistent circulatory failure after cardiac surgery. In ECMO, blood is removed from the venous system and returned to the body via either a vein or an artery after oxygenation and decarboxylation. In veno-venous ECMO, the femoral vein is cannulated so that its tip lies at the level of the renal veins or the inferior vena cava near the right atrium. After oxygenation and decarboxylation, the blood is returned to the venous system through a cannula located in the jugular vein at an adequate distance from the draining cannula. Additionally, the femoral vein and femoral artery may also be used for this purpose. In this method, a leg perfusion cannula is used to prevent limb ischemia [2]. In a report by the Extracorporeal Life Support Organization in 2021, it was stated that a 623% increase was determined in ECMO use, worldwide, since 2009 [3]. However, it also has some disadvantages such as high cost and invasive nature [1]. Also, patients undergoing ECMO are exposed to various complications that increase morbidity and mortality related to the procedure. These complications are associated with underlying critical illness, multiple invasive procedures and devices, including the ECMO cannulas, and the longer intensive care unit (ICU) stay, and consequent nosocomial infections [4]. There is a lack of knowledge on the indications and management of ECMO in the literature. Universal guidelines with expert consensus are required [5].

Scientometrics has been used as a popular statistical method for analyzing scientific literature thoroughly in a certain field [6]. The analysis of scientific information with statistical methods is also known as bibliometrics. With the increase in the number of publications in the literature, studies based on statistical and bibliometric analysis have been carried out on many important medical issues, especially in recent years. This method allows researchers to reach a summary of analysis of a great number of articles on a specific subject in a short time. Also, it gives researchers a future perspective by explaining the current status of a scientific problem. Bibliometrics reveal the most active authors, journals, institutions, countries and the most cited influential studies on a subject or a field [7]. As in other developing methods, best practices in ECMO may be established by the ECMO educational literature [8]. In this study, our aim was to determine the current status of publications about ECMO, determine gaps of knowledge in the literature and guide researchers in this field for future studies.

Material and Methods

This study was based on ECMO publications in the Web of Science® (WoS) database. This platform allows researchers to achieve scientometric and statistical information on a specific subject. We extracted articles on ECMO by entering the keyword "Extracorporeal Membrane Oxygenation" on May 15th, 2023. Publications in the last 10 years were involved. From the database, we investigated the distribution of ECMO articles according to scientific journals. The number of articles, number

of citations and citations per publication for each journal were calculated. Global research productivity, international collaborations, research themes were analyzed using the scientometric method. We also analyzed abstracts and, in case, full texts of the articles. The analysis was performed by the authors independently and controversies were ended after discussions. Document types (Original article, review article, editorial material, early access, meeting abstract, proceeding paper, letter, book chapters, correction, meeting, retraction) were determined. The top 10 authors were listed. Article languages and funding agencies according to the number of publications were listed. Similarly, the top 10 countries and 20 journals according to the number of publications were listed. The impact factors of the journals were also obtained from the official sites of the journals. The number of citations and citations per publication in terms of countries and journals were identified.

In addition, we extracted the top 10 cited articles from the database and made a summary of these articles in order to make a future prediction for researchers in this field.

The data were entered into Microsoft® Excel Programme and results were presented as numbers and percentages. Since any living subject was not involved in the study, ethical approval was not required.

Results

A total of 7940 articles have been extracted since 2014. Of these articles, 6130 (77.2%) were original articles, 1043 (13.1%) were reviews, 320 (4%) were editorial materials. When the top authors according to the number of articles involved were investigated, Brodie D was the top author with 155 (1.9%) articles, followed by Combes A with 126 (1.5%) articles and Lorusso R with 120 (1.5%) articles. English was the most common language. When leading funding agencies were investigated, the United States Department of Health and Human Services (n=348) was on the top of the list, followed by National Institutes of Health Nih USA (n=342) and the National Natural Science Foundation of China (n=112). The details are presented in Table 1.

The United States (the US) was the country that published the highest number of articles (n=3103). The US was also on top in terms of total citations (n=42744) and citations per publication (n=13.7). Germany was in second place with 905 articles, 12397 citations and a ratio of 13.7 citations per publication. China made a contribution with 669 articles, 5721 citations and 8.5 citations per publication, and located in third place. Canada had the highest rate of citations per publication (n=30.3). The US was also in first place when the h-index was considered (n=84). When the first 3 years with the most articles published were investigated, it was determined that the articles intensified in 2020, 2021 and 2022 for all countries. The comparison of productivity in terms of countries is presented in Table 2.

ASAIO Journal was the most popular journal with 491 articles and 6387 citations per publication. The journal in the second place was Perfusion with 384 articles and 2246 citations per publication, followed by the Journal of Cardiothoracic and Vascular Anesthesia with 181 articles and 1536 citations. The performance of the journals is presented in Table 2.

Table 1. Analysis of articles according to document types, authors, funding agencies and affiliations.

Document Types	Number	%
Article	6130	77.204
Review Article	1043	13.136
Editorial Material	320	4.030
Early Access	250	3.149
Meeting Abstract	249	3.136
Proceeding Paper	208	2.620
Letter	168	2.116
Book Chapters	24	0.302
Correction	9	0.113
Meeting	1	0.013
Retraction	1	0.013
Authors		
Brodie D	155	1.952
Combes A	126	1.587
Lorusso R	120	1.511
Schmidt M	98	1.234
Fan E	76	0.957
Maclaren G	75	0.945
Lebreton G	74	0.932
Fraser JF	70	0.882
Shekar K	67	0.844
Broman LM	65	0.819
Languages		
English	7674	96.650
German	124	1.562
Spanish	52	0.655
French	28	0.353
Turkish	21	0.264
Russian	13	0.164
Japanese	6	0.076
Hungarian	5	0.063
Italian	4	0.050
Korean	4	0.050
Funding Agencies		
United States Department of Health and Human Services	348	4.375
National Institutes of Health NIH USA	342	4.299
National Natural Science Foundation of China (NSFC)	112	1.408
NIH National Heart Lung Blood Institute (NHLBI)	103	1.295
National Health and Medical Research Council (NHMRC) Of Australia	61	0.767
German Research Foundation (DFG)	53	0.666
NIH National Center for Advancing Translational Sciences (NCATS)	49	0.616
Projekt Deal	49	0.616
Nih Eunice Kennedy Shriver National Institute of Child Health Human Development (NICHD)	40	0.503
Ministry of Education Culture Sports Science and Technology Japan (MEXT)	35	0.440
Affiliations		
Udice French Research Universities	367	4.609
Assistance Publique Hopitaux Paris (APHP)	310	3.893
(RLUK) Research Libraries (UK)	280	3.516
Columbia University	270	3.391
Sorbonne Universite	257	3.227
Paris Cité University	248	3.114
Harvard University	246	3.089
Institut National De La Sante Et De La Recherche Medicale (INSERM)	233	2.926
Newyork Presbyterian Hospital	212	2.662
Hopital Universitaire Hotel Dieu (APHP)	211	2.650

Table 2. Publication and citation status of the top journals and countries.

	Number of Articles	Total Citations (%)	Citations per Publication
Countries (H-Index)			
The US (84)	3103	42744	13,78
Germany (49)	905	12397	13,7
China (31)	669	5721	8,55
Italy (46)	578	9933	17,19
France (57)	501	13247	26,44
Australia (49)	430	9829	22,86
England (41)	427	7085	16,59
Japan (22)	401	2563	6,39
South Korea (26)	343	2929	8,54
Canada (49)	334	10150	30,39
Journal (2021 Impact Factor)			
ASAIO Journal (3,826)	491	6387	13,01
Perfusion (UK) (1,581)	384	2246	5,85
Journal of Cardiothoracic and Vascular Anesthesia (2,894)	181	1536	8,49
Artificial Organs (2,663)	175	1716	9,81
Critical Care (19,334)	140	4965	35,46
Journal of Cardiac Surgery (1,778)	136	654	4,81
Journal of Thoracic Disease (3,005)	126	1933	15,34
Annals of Thoracic Surgery (5,113)	121	3061	25,3
Journal of Clinical Medicine (4, 964)	97	396	4,08
Frontiers in Medicine (5,058)	91	226	2,48
Journal of Pediatric Surgery (2,549)	91	1174	12,9
Journal of Artificial Organs (1,385)	90	516	5,73
International Journal of Artificial Organs (1,631)	89	488	5,48
Frontiers in Pediatrics (3,569)	82	448	5,46
Intensive Care Medicine (41,787)	81	3161	39,02
American Journal of Respiratory and Critical Care Medicine (30,358)	77	2414	31,35
Medicine (1,817)	73	370	5,07
European Journal of Cardio Thoracic Surgery (4,534)	67	969	14,46
Critical Care Medicine (9,296)	66	1380	20,91
Journal of Critical Care (4,298)	64	915	14,3

When the top 10 articles according to citation numbers were investigated, it was determined that the majority were original articles (8/10). The article entitled "Treatment of 5 Critically Ill Patients With COVID-19 With Convalescent Plasma" published in the Journal of American Medical Association by Shen et al. was the most cited article with 1508 citations. Of the top 10 articles, 4 were on the use of ECMO in COVID-19 patients, 2 were on ARDS and 2 were on cardiogenic shock. A summary of the top 10 articles is presented in Table 3.

Discussion

There is a lack of information on ECMO in terms of scientometrics in the literature. The use of ECMO for treating patients with pulmonary and cardiac failure is becoming more and more widespread. The principle of ECMO depends on temporarily bypassing the functions of the lungs and heart [2]. ECMO supports circulatory functions in a timely manner and provides adequate cerebral blood flow. It is well-known that, with the perfusion of vital organs, ECMO improves survival and neurological outcomes [3]. As mentioned above, there are various techniques that may be preferred for patients requiring

ECMO. It has recently been reported that while veno-arterial ECMO had a mortality rate of 55%, veno-venous ECMO had a mortality rate of 42%. There is an ongoing debate in the literature to decrease mortality and researches are ongoing to create ideal guidelines describing indications and applications of ECMO in combination with serum laboratory data [9,10]. Even though it has many advantages, patients receiving ECMO are at risk of life-threatening complications such as bleeding, thrombosis, and infection [11].

Bibliometrics, also known as the "science of science" may help researchers in this field to share and spread their experiences and knowledge in order to establish accurate guidelines.

The use of ECMO in clinical practice attracts the attention of more and more clinicians dealing with cardio-respiratory failure. Accordingly, the number of publications on ECMO tends to rise gradually each year. In a bibliometric study about ECMO, it was stated that half of the articles (n=550) about ECMO were published in the 2010s. By the 2000s, they could determine 27 publications and only 15 in the 1990s [12]. The reason for this large increase in publications may be linked to more availability and growing experience about ECMO all over the world.

Table 3. Summary of top ten articles about ECMO.

Article Information [Reference No]	Category	Country	Number of Citations	Summary
Chenguang Shen et al. [17] Treatment of 5 Critically Ill Patients With COVID-19 With Convalescent Plasma Journal of American Medical Association	Original Article	China	1508	Five patients with confirmed COVID-19 and ARDS gained improvement in their clinical status after administration of convalescent plasma containing neutralizing antibodies. Four patients who had been receiving mechanical ventilation and ECMO no longer required respiratory support by 9 days after plasma transfusion.
Alain Combes et al. [18] Extracorporeal Membrane Oxygenation for Severe Acute Respiratory Distress Syndrome New England Journal of Medicine	Original Article	France	1071	Patients with very severe ARDS have undergone ECMO and were compared with the control group. Of 124 patients, 44 died. The frequency of complications did not differ significantly between groups, except that there were more bleeding events leading to transfusion in the ECMO group than in the control group. ECMO did not improve 60-day mortality.
Guido Tavazzi et al. [19] Myocardial Localization of Coronavirus in COVID-19 Cardiogenic Shock European Journal of Heart Failure	Case Report	Italy	614	A 69-year-old patient developed respiratory distress, hypotension and cardiogenic shock due to COVID-19-related myocardial infarction. The patient was successfully treated with ECMO.
Richard Cheng et al. [20] Complications of Extracorporeal Membrane Oxygenation for Treatment of Cardiogenic Shock and Cardiac Arrest: A Meta-Analysis of 1,866 Adult Patients Annals of Thoracic Surgery	Meta-Analysis	The US	528	A systematic scientific database search on ECMO for treatment of cardiogenic shock or cardiac arrest in adult patients. A total of 20 studies with a total of 1866 patients were included. ECMO may help survival but its numerous complications should be considered and risk-benefit evaluation should be carefully assessed.
Matthieu Schmidt et al. [21] Predicting Survival After ECMO for Refractory Cardiogenic Shock: The Survival After Venous-Arterial-ECMO (SAVE)-Score European Heart Journal	Original Article	Australia	479	A total of 3846 patients with cardiogenic shock treated with ECMO were included in the study. Of these patients, 1601 (42%) survived. Chronic renal failure, longer duration of ventilation prior to ECMO initiation, pre-ECMO organ failures, pre-ECMO cardiac arrest, congenital heart disease, lower pulse pressure, and lower serum bicarbonate (HCO ₃) were risk factors associated with mortality.
Ryan P. Barbaro et al. [22] Extracorporeal Membrane Oxygenation Support in COVID-19: an International Cohort Study of the Extracorporeal Life Support Organization Registry LANCET	Original Article	The US	468	Data of 1035 patients with COVID-19 who received ECMO support were included in this study. In patients with COVID-19 who received ECMO, both the estimated mortality 90 days after ECMO and the mortality in those with a final disposition of death or discharge were less than 40%.
Matthieu Schmidt et al. [23] Predicting Survival after Extracorporeal Membrane Oxygenation for Severe Acute Respiratory Failure: The Respiratory Extracorporeal Membrane Oxygenation Survival Prediction (RESP) Score American Journal of Respiratory and Critical Care Medicine	Original Article	Australia	452	A study was conducted with 2,355 adult patients with severe acute respiratory failure treated by ECMO from 2000 to 2012. The data were obtained from the Extracorporeal Life Support Organization international registry. Respiratory ECMO Survival Prediction score was applied and was found to be relevant and validated tool to predict survival for patients receiving ECMO for respiratory failure
Ryan P. Barbaro et al. [24] Association of Hospital-Level Volume of Extracorporeal Membrane Oxygenation Cases and Mortality Analysis of the Extracorporeal Life Support Organization Registry American Journal of Respiratory and Critical Care Medicine	Original Article	The US	411	A retrospective analysis of an international registry of ECMO support from 1989 to 2013. Patients were divided into 3 groups according to age: neonatal (0–28 d), pediatric (29 d to 18 yr), and adult (>18 yr). It was observed that survival rate improved among neonates and adults in 1989–2013.
Dion Stub et al. [25] Refractory Cardiac Arrest Treated with Mechanical CPR, Hypothermia, ECMO and Early Reperfusion (the CHEER Trial) Resuscitation	Original Article	Australia	404	The CHEER trial (mechanical CPR, Hypothermia, ECMO and Early Reperfusion) was applied to 26 eligible patients with cardiac arrest. It was found that mechanical CPR, peri-arrest therapeutic hypothermia and ECMO are feasible and associated with a relatively high survival rate.
Parham Sadeghipour et al. [26] Effect of Intermediate-Dose vs Standard-Dose Prophylactic Anticoagulation on Thrombotic Events, Extracorporeal Membrane Oxygenation Treatment, or Mortality Among Patients With COVID-19 Admitted to the Intensive Care Unit The INSPIRATION Randomized Clinical Trial Journal of American Medical Association	Original Article	Iran	363	Multicenter randomized trial with a 2 × 2 factorial design performed in 10 academic centers in Iran comparing intermediate-dose vs standard-dose prophylactic anticoagulation and statin therapy vs matching placebo among adult patients admitted to the ICU with COVID-19. Patients receiving ECMO were excluded.

As ECMO is a relatively novel model, researchers may have a great will to make publications and lead the literature in this untouched field.

In a similar but relatively old study, Wang et al. conducted a 10-year bibliometric analysis of ECMO studies and revealed that the number of articles published in the past decade has increased, especially from 2019 to 2020 [13]. This fact proves that actual bibliometric analyses on ECMO are essential to reveal the current status of ECMO applications. Recent information on ECMO may affect and guide future perspectives.

Generality of ECMO among different countries also has a property that it may show the level of development. It has been reported that the number of ECMO-related publications tends to decrease in non-developed countries. Additionally, the US has been reported to be the leading country in terms of the number

of publications [12,13]. In another study, the US was the leading country in terms of COVID-19-related ECMO studies followed by Germany and Japan [7]. In our study, accordingly, the US was the leading country in both number of publications and number of citations. While Germany is in second place, China took the third row from Japan. It was reported that the attention to ECMO was gradually increasing in China [14]. With increasing funding for research and development in China, the number of scientific articles is rising in parallel.

The University of Michigan was the institution that had the largest number of publications and the highest centrality. In the above-mentioned article, when the most productive authors were investigated, Daniel B was the author who had the largest number of publications [13]. Since our study is a recent one, Brodie D was found to be the author with the highest number

of publications.

In a study, the top 3 journals with the highest number of publications were ASAIO Journal (n = 36), *Frontiers in Medicine* (22), and *Perfusion-UK* (n = 20) [7]. In our study, ASAIO published the highest number of articles. According to the official website, the current Impact Factor of ASAIO journal is 2.872 with no page charge and has a decision time of less than 1 month. The journal features peer-reviewed articles on the newest and most innovative technology, organ repair, regeneration and development, preclinical testing, and clinical outcomes. There are 12 issues per year. Journals that focus on novel methods like ECMO increase their popularity and thus, the citations they get. Another parameter to measure the importance given to scientific development is the number of citations of articles. The number of citations gained by an article is commonly used as an indicator of its importance in the literature. The impact of research on clinical practice can also be detected with the number of citations [15]. In terms of the number of citations, the USA and ASAIO journal were on the top of the list.

The ECMO literature was reported to focus on the treatment of ARDS, prevention of coagulation system-related complications, use in neonatal and pediatric patients, mechanical circulatory support for cardiogenic shock, and ECPR and ECMO during the COVID-19 pandemic [14]. Analysis of the top 10 articles revealed that most of the articles were related to ECMO in the treatment of COVID-19 patients. Eight of the 10 articles were original articles. Treatment of ARDS and cardiogenic shock were also popular subjects among researchers. It is observed that the pandemic dominated not only social life but also scientific literature.

Conclusion

In conclusion, even though it has lethal complications, ECMO use is becoming increasingly common due to its utility in patients with pulmonary failure, cardiogenic shock, circulatory instability during high-risk PCI and persistent circulatory failure after cardiac surgery. In concordance, the number of publications on ECMO is growing rapidly over the years. The need for accurate guidelines on ECMO makes the ECMO literature inevitably important. Bibliometric studies not only reveal the scientific status of ECMO but also give perspective for future studies. According to our results, the number of publications and the number of citations a country gain is parallel to the development level. Journals should focus on novel methods in order to increase their popularity among researchers. The support of educational institutions and funding agencies has an undeniable effect on determining the leader in a scientific field.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

The authors declare no conflict of interest.

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